

AN EFFECT OF BIODIESEL ON COMPRESSION IGNITION ENGINE VIBRATION - A REVIEW

ADHIRATH MANDAL¹ & HAENGMUK CHO²

¹Doctorate Student, Department of Mechanical Engineering, Kongju National University, Republic of Korea

²Professor, Department of Mechanical Engineering, Kongju National University, Republic of Korea

ABSTRACT

There has been a continuous demand of conventional fuels for the transport sector. But we only have a limited amount of fossil fuels. The fossil fuels are a non-renewable source of energy. Moreover, in the developing countries diesel engines are used to produce electricity or in the agricultural land. As the fossil fuels are depleting day by day we need to have an alternate source of fuel. Biodiesel, which is a renewable energy, and has similar properties like the conventional diesel fuel. Biodiesel also has more oxygen content which helps in reducing the CO and HC in the exhaust emission. As Biodiesel is a new fuel which is being discovered, the performance of the engine is an important issue. The performance of the engine can be affected by combustion, excess vibration in the engine body or because of the fuel mixture. Engine vibration is a major disadvantage as it reduces the efficiency of the engine and too much of the vibration can lead to catastrophic effect. This paper focuses on the engine vibration which are caused by the different biofuel blends. It also focuses on how with the injection of hydrogen in the intake manifold can change the level of vibration.

KEYWORDS: Biodiesel, Vibration, Intake Manifold, Hydrogen & CNG

Received: Nov 05, 2018; **Accepted:** Nov 26, 2018; **Published:** Dec 22, 2018; **Paper Id.:** IJMPERDFEB20197

1. INTRODUCTION

The internal combustion engine is used in many areas. It can be used in power production to power a vehicle. In an internal combustion engine the diesel engines are very popular because of their various prominent advantages, such as High Stability, high energy efficiency and its flexibility for various operations. Diesel engines are also used widely in the production of electricity and used in the farm land for agricultural purpose in the urban areas of India. It is expected that 40 million diesel engines are used in India 1. The internal combustion engine in today's world is mainly dependent on conventional fuels. The dependency on conventional fuel are becoming unavoidable and we will face shortage issue because of the industrialization and the growing population. There are three types of fossil fuels which are mainly used i.e. oil, natural gas & coal, and 80% energy are generated from these fossil fuels. 98% energy is generated by carbon emission from the combustion of the fossil fuels. But fossil fuels are non-renewable. In today's world the increasing automobile requires a lot of fuel to run the vehicles 26. The oil wells are drying up and it is expected to go extinct 27. This is one of the reasons the scientists are trying to shift from fossil fuels to alternate clean fuels. Fossil fuels are depleting, not the only reason the scientists are shifting, and emission regulations are also changing and becoming stringent day by day 3. After eight decades the people are getting aware about the environmental pollution. So search for alternate fuels are going which could burn with less pollution 24.

Because of the shortage of the fossil fuels and burning of the fossil fuels cause environment pollution, which can lead to global warming, the scientist has discovered alternate fuels such as bio-diesel. As the environment is mainly concerned with the emission of the exhaust gas, this has been encouraging biofuel to be used [27]. Biodiesel, which is a blend of fatty acid alkyl esters, which is produced from animal fats such as duck fat, chicken fat, goat tallow and vegetable oils such as Jatropha oil, cotton seed oil, algae oil, soybean oil, jojoba oil, rocket seed oil and frying oil. Properties of biodiesel are similar to conventional diesel fuel that is a biodegradable and non-toxic fuel. Moreover biodiesel accommodate more oxygen, which helps in reducing CO, HC and smoke opacity in the vehicle exhaust⁴. Vegetable oils have high viscosity, makes it difficult to use directly in the engine. Vegetable oil can be used in the engine in five different ways: first by direct use/blending, second by hydrotreated vegetable oil, thirdly by micro-emulsion, fourthly by pyrolysis and fifth by transesterification. It was stated that for biodiesel blends the maximum heat release rate is lower than base line mineral diesel. Lower heat release rate was responsible for higher viscosity, shorter ignition and lower calorific value⁴.

IC engines have a significant amount of noise and vibration in the vehicle⁵. Vibrations can be defined as fluctuations of the mechanical components or structural system about an equilibrium position. If the vibrations are not controlled then it would generate a fatal situation²². A. Keskin stated that use of natural gas reduces the vibration in the engine²³. The investigation has been carried out on the feasibility of the Biofuels on emission and performance characteristics. The main problems that are occurring frequently are the maintenance, erratic and irregular combustion, which gives rise to erosion of the combustion chamber and the piston head, knocking, vibration of the body and the CI engine. A good biodiesel may not have a lasting characteristics because of its vibration. The thermal efficiency is also deteriorated because of the engine knock and detonation during the engine combustion. Too much of the vibration will damage the engine and will reduce the life of the engine⁶⁵.

2. LITERATURE REVIEW

Ahmad Taghizadeh-Alisaraei et al.⁷ studied the faults causing the lower efficiency, noise pollution and abrasion in the parts of the diesel engine. They studied the vibration, combustion and the knocking in the diesel engine. The fuels used were 100% diesel, 20% biodiesel, 40% biodiesel, 60% biodiesel, 80% biodiesel & 100% biodiesel. The biodiesel used was produced from waste cooking oil to characterize the non-stationary and noisy vibration signals two time-frequency representation was used. The experiment was conducted on two, four stroke diesel engine, a six cylinder engine and a single cylinder engine. The rotational speed was stabilized and controlled with a governor.

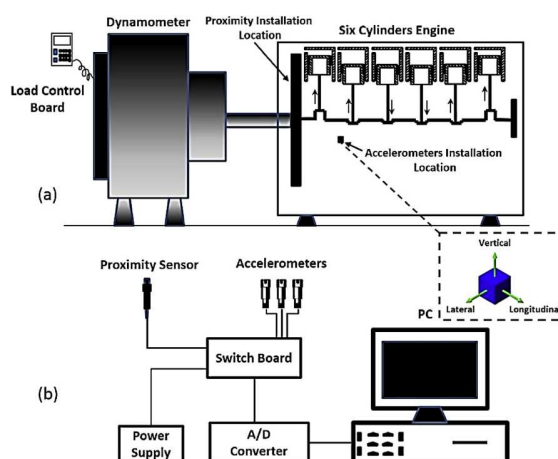


Figure 1: The Schematics of Experimental Set Up;
a) Load Control by Dynamometer,
b) Data Collection Set Up

To measure the engine vibration, they used three accelerometers were used. Proximity sensor was used to measure the engine crankshaft angle. The engine was run at different rpm level from 1000 to 2200, with 200 increase every time in ideal condition. And under load condition, the engine was run at 1400 to 2000 rpm with 200 increase in rpm in every step. It was also seen that if there is a fault on the valve and the injection unit there would cause a vibration of the range of 7 to 25 kHz. The results showed that the biofuel blend effects the injectors spray which leads to vibration, variable power and variable combustion. It was also seen that the blend B40 had the highest vibration. It was also observed that the smoothest performance was with the B40 biodiesel blend. B40 had the largest amount of combustion energy, but the losses were through vibration. Injector were also replaced with new one and it was seen that the engine had a smooth performance. The improvement was 9% smoother for diesel engine. This concludes that injector spray effects the vibration. **AhmetÇalık** compared the vibration characteristics of pure diesel with alternate fuel. Diesel engine was used. Pure conventional engine was used as a reference fuel. The biodiesel used in this study was produced from waste cooking oil. Hydrogen was also added through the intake manifold. Observation was done when hydrogen was added to the intake manifold and the vibration was measured. If free fatty acids content is high in triglyceride, Alkali-catalyzed transesterification reaction would not be able to occur. 4 stroke and 4 cylinder compression ignition engine that was naturally aspirated was used. H_2 was supplied to the intake manifold at a rate of 5l/min. experiment was conducted at different rpm intervals between the range of 1200-2400rpm with 300 increase at every step. Accelerometer was used to measure vibration and the accelerometer was bonded to engine with quick adherent gel. Data was recorded in three different directions (i.e.x,y,z direction).

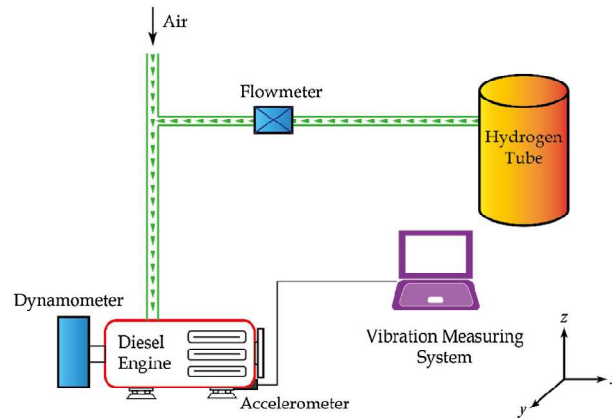


Figure 2: Experimental Layout 1

Revolutions per minute (rpm) was calculated by the following formula:

$$a_w = \sqrt{\frac{1}{T} \int_0^T a_w^2(t) dt}$$

a_w (m/s²) = weighted acceleration,

T = measurement time

Total vibration was given by:

$$a_{total} = \sqrt{a_{vertical}^2 + a_{lateral}^2 + a_{longitudinal}^2}$$

It was observed that the engine speed affected the engine vibration, with an increase in the engine speed the vibration also increases. Waste cooking oil biodiesel decreased the engine vibration, as there was better combustion and reduced ignition delay. With the addition of the H₂ in the intake manifold, there was a further reduction in the vibration both in the case of diesel and biodiesel. As H₂ has less ignition delay because of fast combustion, it reduces the vibration. Though waste cooking oil showed minimum vibration with the use of H₂ gas. **Chetankumar Patel et al.**⁸ experimentally studied the vibration, noise, spray and combustion characteristics on a single cylinder compression ignition engine. These types of engines are mainly used in agricultural farm machinery and genset. The experiment was conducted with three different types of biofuel blends: baseline mineral diesel, Karanja biodiesel & 20% (v/v) Karanja biodiesel blend. A spray visualization experiment was conducted in a constant volume spray chamber. Engine noise as well as vibration were measured. The results showed that increased ambient pressure resulted in reduction in spray penetration. Biodiesel had a retarded spray when compared to diesel. The noise produced by KB20 was the highest, it was also observed that KB100 had more noise, but was marginally more than mineral diesel. KB20 produced the highest vibration. The vibration was in the vertical direction and it was because of the combustion, which produces thrust on the piston which acts in vertical direction. Fuels which produce more Heat release rate will generate high pressure rise rate which is also a reason for high vertical vibration. **Kerimcan Celebi et al.**⁹ experimented with pongamia pinnata and tung oils, which are pure biodiesels. The performance and emission parameters and injectors life are mainly affected by the fuels viscosity. Biodiesel were blended with low sulphur diesel in the ratio of 50% and 75%. Hydrogen gas was also injected into the intake manifold. It was done to evaluate its effect when high viscous liquid fuels were used. Seven different types of fuels were used D100, PP50, PP75, PP100, T50, T75, T100. It was seen that the highest viscosity was found in PP100 fuel and

the lowest viscosity was in D100 fuel. The experiments showed that with the load conditions more brake specific fuel consumption (BSFC) was observed with increase in the biodiesel ratio. But with the addition of H_2 the brake specific fuel consumption reduced. Tung biodiesel blends had lower brake specific fuel consumption than pongamiapinnata biodiesel. Frequency-time spectrum showed that higher biodiesel content, decreased the vibration acceleration of the engine block. The highest vibration was found with Tung Biodiesel when compared to PongamiaPinnata biodiesel. It was noted that the increase in compression ratio the vibrational acceleration decreases. Higher cetane number of the fuel effects the ignition delay and pressure rise improves the combustion characteristics. Biodiesel fuel has high viscosity which decreases maximum pressure and lowers engine body vibration. The injection of H_2 in the intake manifold further reduced the vibration for both low and medium load conditions. It was also observed that with the increase of load, the vibration in the body increased. **ErinçUludamar et al. 10** discussed about the addition of HHO (hydroxyl gas) gas in the internal combustion engine which was run by Biodiesel fuels. Different types of biodiesel were used, canola biodiesel, Corn Biodiesel and Sunflower Biodiesel. The study was aimed at the effect of HHO generation system and to find the vibration characteristics of diesel engine which was run on different biodiesel. Biodiesel blends were prepared in the volumetric ratio of 20% and 40% for each blend. A four stroke, four cylinder, direct injection diesel engine of Mitdubishi Canter was used and was filled with low sulphur diesel, 20%20% and 40% canola biodiesel low sulphur diesel fuel blend, 20% and 40% sunflower biodiesel e low sulphur diesel fuel blend and 20% and 40% corn biodiesel e low sulphur diesel fuel blend. The HHO was injected into the intake manifold with varying flow rate, 2 L/min, 4 L/min, and 6 L/min. The engine was run at different RPM, 1200, 1500, 1800, 2100 and 2400.the results showed that 20% corn biodiesel + 80% low sulphur diesel fuel improved the Vibration by 5.98%. In CI engine vibration are mainly because of pressure in the cylinder. Biodiesel has better oxygen contamination which promotes better combustion quality of the cylinder. CoB20 had a lower cetane number which can be related to increased vibration. With the addition of Hydroxy gas the maximum reduction in the vibration was 3.54% with HHO at 6 L/min. HHO gas has H_2 and O_2 , which improves the mixture for combustion and reduces vibration. **ErinçUludamar et al. 11** investigated the noise and vibration characteristics of a diesel engine that was run by biodiesel blend. The biodiesel blend used in the experiment was sunflower, corn and canola oil. The biodiesel sample was produced by transesterification reaction. For this reaction sodium hydroxide and methanol were used.

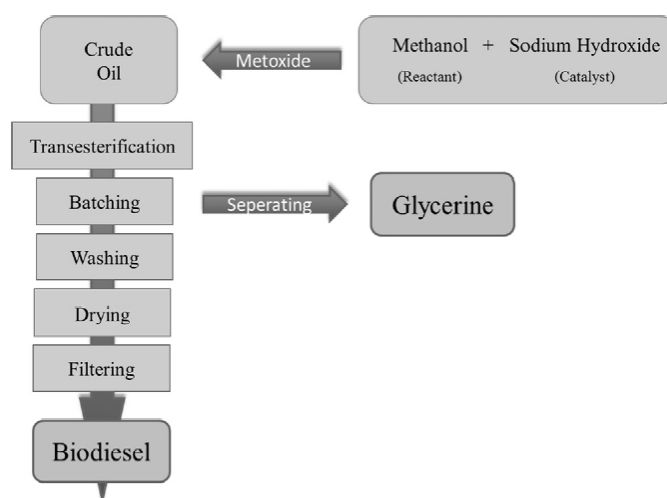


Figure 3: Step to Produce Biodiesel 11

Test fuels were prepared in different blends ranging from 20% to 100% pure low sulphur diesel and mixed with biodiesel in the proportion of 20% to 100% sunflower, canola and corn. In the experiment a four stroke, four cylinder and a direct injection diesel engine were used. Before doing the experiment the fuel was cleaned and then the blend was tested at 1200,1500,1800,2100 and 2400 rpm with no load condition.

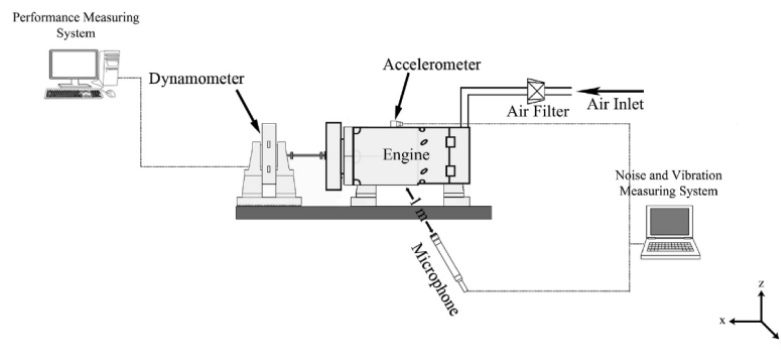


Figure 4: Experimental Layout 11

It was observed that the average of engine vibration increased with an increase in engine speed, this was due to the inertial force of the crank rotational speed. The engine vibration decrease by 1.72%, 2.37%, 0.5% for SB20, CaB20, CoB20; 2.38%, 2.79%, 0.98% for SB40, CaB40, CoB40; 2.28%, 2.44%, 2.11% for SB60, CaB60, CoB60; 4.60%, 5.76%, 3.19% for SB80, CaB80, CoB80 and 2.80%, 3.87%, 3.72% for SB100, CaB100, CoB100, respectively when compared with 100 pure diesel. The reduction in vibration was because biodiesel contains extra oxygen, so the quality of combustion of the biodiesel is better than conventional diesel fuel. **Chetankumar Patel et al. 12** discussed about the use of jatrophabiodiesel in the genset engine and analysed the vibration, noise and combustion characteristics. The biodiesel blend used in the engine was 100% jatropa biodiesel, 20% jatropa and 80% diesel and 100% mineral diesel. The vibration was recorded and it was seen that the vertical vibration was because of the piston motion. The engine showed maximum vibration in vertical as well in lateral direction when it was fueled with JB20 biodiesel. The vibration was 7-25% more than the mineral diesel. When the engine was filled with JB100 the vibration was least, the vibration was 1-25% less than mineral diesel. Analysis showed that as the O₂ content and calorific value increases the vibration decreases. But with the increase of viscosity the vibration characteristics increases.

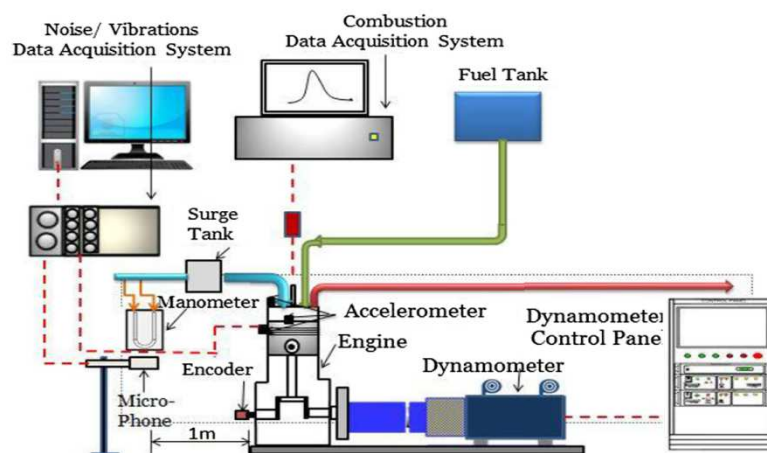


Figure 5: Experimental Setup 12

Syed Javed et al. 6 studied the vibration of diesel engine using biodiesel fuel. Fuel used in the study was jatropha methyl ester. Nano particles of ZnO were used at a concentration of 100 ppm of 20 and 40 nm size. These particles were suspended in the jatropha biodiesel blend by ultrasonic process. A four stroke, single cylinder direct injection diesel engine was used for the test. JME30% diesel 70% and ZnO 20 showed the highest peak of resonance whereas JME20% diesel 80% and ZnO 20 showed the lowest. It was also inferred that as the nano particles size increase the combustion characteristics improve. With the hydrogen flow rate at 1.5 l/min B30JME40 and B20JME40 had improved vibration characteristics. It was observed that with the application of peak load B20JME20 showed the lowest vibration but for all load conditions B30JME40 & B20JME40 showed low vibrational characteristics. B20JME20 showed better vibrational characteristics at

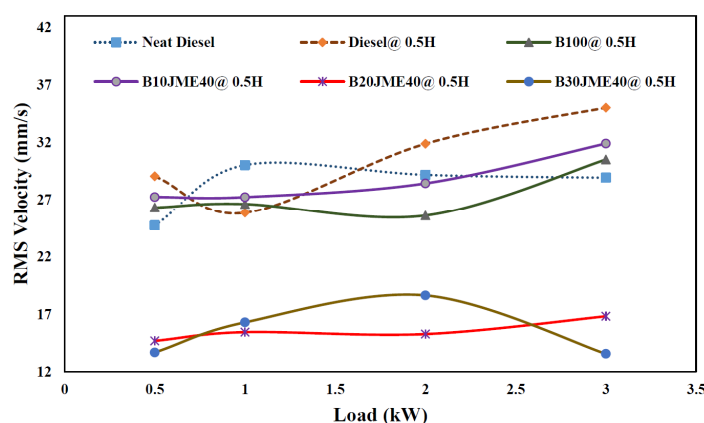


Figure 6: H₂Flow Fate of 0.5 l/min, 40nm ZnO, Variation of RMS6

Peak load when hydrogen flow rate was 1.0 l/min. with ZnO nano particles of 40nm size exhibited better vibration amplitudes with B20 and B30 fuel blends. As the nano particle size increase there is an increase in catalytic behaviour and increase in combustion and reduces vibration. There is high heat release rate, oxidization and metal vaporization. **Ahmad Taghizadeh-Alisaraei et al.** observed that the sound and vibration of the diesel engine have a direct effect on the user. To study this he used a single differential tractor engine. It was also noted that the engine vibration was felt on the tractor driving seat. To understand it better, the moving parts were studied that are piston, crankshaft and the connecting rod. Vibration are mainly caused because of the change in the gas pressure inside the cylinder and next because of the inertial force that are concentrated on the different engine parts. The experiment was conducted with 9 different types of biodiesel blends. The biodiesel was produced from vegetable oil (soybean and canola), waste oil and animal fats based on ASTM D 6751-09 standard. The different blends were B5, B10, B15, B20, B30, B40, B50, pure petro diesel & pure biodiesel.

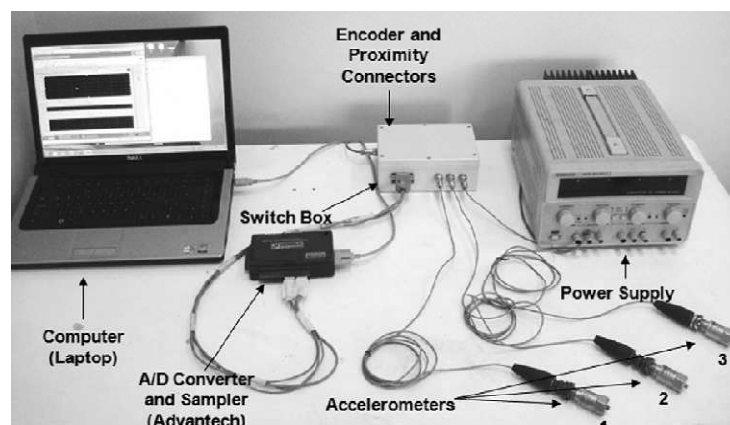


Figure 7: Engine Vibrations Measurement Setup 13

Accelerometer, proximity sensor and encoder were used in the experiment and were connected with the switchbox. 3 accelerometer were used for the measurement of vibration in vertical, lateral and longitudinal; z,y and x axes respectively. The data of vibration were collected at two different conditions, first before service and second after service. The results showed that most of the vibration rises between 1800-2000 rpm. The mean increase of the total vibration of all the fuels were between 35.11 m/s^2 before service and after service 26.21 m/s^2 . with the service there was a reduction of 12% in the vibration. B20 and B40 showed the lowest vibration. B40 showed 51.47 m/s^2 before service and 45.02 m/s^2 after service, whereas B20 showed 52.13 m/s^2 before service and 46.06 m/s^2 after service. It was noted that B15 and B30 had the highest vibration. Change in gas pressure inside the cylinder were least for B40 so it gave less vibration. **Giancarlo Chiatti et al. [14]** demonstrated that biodiesel are more environmentally sustainable. The main aim of the paper was to investigate the Vibro-acoustic behaviour of a small displacement engine. A two cylinder, common rail diesel engine was used which was water cooled. The instantaneous pressure was measured by removing the heating plug in one of the cylinders. The pressure was measured by piezoelectric pressure probe. The vibration and noise was measured by Endevco 7240C mono-axial piezoelectric accelerometer and microphone. For the measurement of the vibration the accelerometer was mounted at the top of the engine. This position was selected as it gave high sensitivity. The second generation biodiesel was mixed with USLD. The biodiesel blend was in the ratio of B40 (60% USLD and 40% Biodiesel), B10 and B20 were used. The results showed that the vibrational characteristics almost overlap for USLD fuel and B10 Biodiesel fuel. It was also seen that the vibrational signals and the in cylinder pressure overlapped with B10, B20 and B40. load condition also affects the vibration which were caused by combustion. As biodiesel blend increase the volume percent which changes the droplet size in spray and the evaporation rate. **Erinç Uludamar et al. 5** experimented to comprehend the noise and vibrational characteristics when three different types of biofuel blends were used in different ratios with the effect of H_2 in the intake manifold. The different biodiesel used in the study were Canola, Sunflower and corn biodiesel. They were prepared by transesterification reaction, using 6:1 methanol to oil molar ratio and sodium hydroxide as a catalyst. The blends were prepared with low sulphur diesel fuel in the ration of 20% and 40 % for each biodiesel. A four stroke four cylinder direct ignition Mitsubishi canter diesel engine was used for the experiment. For the experiment 100% low sulphur diesel, SB20, SB40, CaB20, Cab40, CoB20 and Cob40 was used with H_2 in the intake manifold with a flow rate of 3 l/m and 6 l/m. the engine vibration were collected for 10s for each experiment from the engine block with the sampling frequency 51.2 kHz . Upward and downward movement of the piston caused the maximum root mean square value. The maximum RMS value Z-axis. The conversion of the linear motion to the rotational motion of the crankshaft increased the RMS values in the X-axis. The vibration decreased with the increase of the biodiesel blend. The decrease was 1.72%,

2.38%, 2.37%, 2.79%, 0.5%, and 0.98% for the SB20, SB40, CaB20, CaB40, CoB20, and CoB40, respectively compared to D100. The decrement of vibration was due to the extra oxygen in the biodiesel. which helps in better combustion. But with the addition of H_2 in the intake manifold there was a further decrease in the vibration. With H_2 at 6 l/min the vibration was minimum. Biodiesel and H_2 causes ignition delay and change in peak pressure rise rate causes decrease in vibration.

KerimecanÇelebi et al. 15 proposed to replace the conventional diesel engine with the alternate fuels because of the greater interest because of the environmental issue. During their work the engine was fueled with conventional diesel, canola and sunflower biodiesel blend. The biodiesel fuel were produced by transesterification reaction. The fuel properties were also tested. For the experiment conventional diesel was blended with biodiesel in the ratio of 20% and 40% by volume. The engine used to be a four stroke, four cylinder engine. The fuel line was cleaned before commencing the experiment. Five different rpm speed were selected for the experiment, from 1200 rpm to 2400rpm with 300 increment under no-load condition. The vibration samples were collected for 10s for every experiment. The results showed that with increase of engine speed the engine vibration increased. This was due to the inertial forces. The vibration of the engine block was reducing for each biofuel blend when CNG flow rate increased. The engine vibration increased between the range of 1800rpm to 2100rpm for 20% biodiesel fuel without the addition of CNG, when compared to conventional diesel. When 40% biodiesel were used it increased the vibration only for 1800rpm to 2100rpm, but for other engine speed the vibration were reduced. Reduction in vibration is mainly because of the fuel properties which effect the combustion in cylinder such as; combustion during ignition delay and peak pressure rise rate. Oxygen content in the biodiesel reduces the vibration. Introduction of CNG fuel reduces the vibration acceleration. The reduction were 2.7% for NG5, 5.5% for NG10, and 8.1% for NG15 compared to 0% natural gas (NG). **Chetankumar Patel et al. 4** observed that in rural areas the engine are very noisy and emit toxic pollutants. So it was experimental investigations were carried out on single cylinder engine to judge the vibrational and noise characteristics when the engine was fueled with rapeseed and soybean biodiesel. The experiment were carried out in engines which are typically used for genset and for machines that are used in the agricultural farm. The vibration were measure in vertical, longitudinal and lateral direction by using miniature tear drop CCLD accelerometers (B&K; 4517). The sensitivity was 10 mV/g. The heat release rate was maximum for mineral diesel, followed by S20, SB20 and SB100 in the premixed combustion phase. Vibration was observed to be maximum in the vertical direction as it was the direction of the motion of the piston. The base mineral diesel showed higher vertical and lateral vibration compared to soybean based biodiesel. S20 and SB20 showed higher vibration in longitudinal direction when compared to baseline mineral diesel. It was seen that there was a reduction of 8-30% vibration in all load of the biodiesel in the SVOs compared to mineral diesel. It also observed that the HRR is related to vibration, if HRR premix combustion decrease the vertical vibration also decrease. **B. Heidary et al.** studied to examine the vibration caused by different diesel and biodiesel blends. It was studied in power tiller engine. The main aim was to reduce the engine vibration. The experiment was conducted on a single cylinder 13 hp power tiller. Six biodiesel fuels were prepared and used in this study. The blends were B5, B10, B15, B20, B100 and pure diesel. The biodiesel in the study were prepared from vegetable oil, animal fats and waste oils. Five different speed levels of the engine were used, 1400, 1600, 1800, 2000, 2200 r/min. The sampling rate of the data were 80,000 and 2s recording time. Results showed that the main reason for vibration was because of the piston stroke. The increase in speed increases the vibration. It was also seen that the axis of movement was significantly affect the vibration acceleration. **H.G. How et al. 17** investigated the combustion, performance, emission and vibration characteristics of a CRDE which was run by coconut biodiesel. The experiment was conducted with different load options (0.17, 0.34, 0.52, 0.62 & 0.86 MPa). The fuel used were B10, B20, B30, B50 & conventional diesel. Glow plug was removed and pressure sensor was mounted in the head of the first cylinder. Vibration was measured in the lateral and

perpendicular to the cylinder axis. 2000rpm was kept constant to conduct all the tests, the RMS of acceleration were affected by the engine load and the biofuel blend. B50 showed lower RMS acceleration than conventional (baseline) diesel under all loading conditions. Vibration was least with B50 blend at 0.86MPa and reduction was 13.5% respect to baseline diesel. B50 had lowest vibration, this was mainly because of the rapid change and cylinder pressure fluctuations. **S. Jindal 18** studied the effect of engine operation parameters i.e. Injection pressure & compression ratio on the vibration of the engines. Biodiesel blends and diesel were used to run the engine. Vibration were measured at two locations first on the head of the cylinder and secondly on the cylinder block placed horizontally in perpendicular direction of the crank axis. The biodiesel were prepared in the laboratory from vegetable seed oil. It was seen that 20% blend of vegetable oil was good for the working of CI engine. At full load the engine runs smoothly. It was also seen that for smooth running a higher compression ratio was preferred. B50 was preferred in regards to B20 in terms of vibration point of view. At no load the torque were unbalanced so the vibration were more but when load was applied the torque was balanced and vibration were less. Increase in the compression ration decreases the vibration because of delay period which reduces knocking. With the increase in ignition pressure the mixing of diesel and air is better which leads to complete combustion and reduce vibration. **Mohammed FaizanShaikh et al. Error! Reference source not found.** compared the vibro-acoustic behavior of a compression ignition engine by using biodiesel and its different blends, diesel at different load conditions. A single cylinder four stroke diesel engine was used in the experiment. To change the load conditions, eddy current type dynamometer was used and was connected to the engine. The biodiesel used in the experiment was Jatropha biodiesel (produced by transesterification). Six different types of blend were prepared, B5, B10, B20, B50, B100 and B00 (pure biodiesel). A load of 0,5,10 and 15Kg was implied in the engine. Recording of vibration in two different direction was done. Firstly horizontally on the engine cylinder block and second perpendicular to the engine cylinder block. It was seen that with the increase in the percentage of biodiesel the vibration reduces by 15%to 27%. In the comparison of the Jatropha biodiesel and conventional diesel the vibration was lower in case of Jatropha biodiesel blend.This was because the diesel fuel has a higher calorific value. **K. PrasadaRao et al. 21** experimented onfilledect diesel injection engine, which was fueled with Mahua methyl ester with methanol additive blend to study the combustion, cylinder vibration and heat release rate. A four stroke, single cylinder IDI variable engine with forced air and oil cooled engine was used in this study. Five different types of methanol in MME were used. The ratio of the blend was 1/99%, 2/98%, 3/97%, 4/96% and 5/95% by volume additive methanol is added to MME. The load conditions were No Load, 0.77 kW, 1.54 kW, 2.31 kW and 2.70 kW. Vibration of the engine was measured in two directions, first in the direction of piston slap and other being vertical. Results showed that there are three zones, first zone belongs to air pump vibration, second zone is the combustion in pre-combustion chamber and the third zone is the indication if the combustion in the main combustion chamber. 3% additive showed smoother combustion in the cylinder head. The paper concluded that with the addition of 3% methanol in MME it gives optimum performance and the diesel can be replaced with MME biofuel. **Mustafa Karagöz et al. [24]** studied the effect of CO₂ in biogas on the performance and the vibration developed in a spark ignition engine. The experiment done on a biogas generator. The generator was a diesel engine and was modified by adding a spark plug. Load was applied by the generator o the engine from 0 to 9kW, with 1.5 kW increment. The accelerometerwas fixed in three direction longitudinal, lateral and vertical. The CO₂ in the biogas was adjusted in two levels, i.e. 13% and 49%. It was observed that the burning characteristics changes the vibration amplitude. On the lateral axis the highest value of vibration were obtained for both the fuels. The 13% CO₂ biogas with zero load showed the lowest vibration in the longitudinal direction. Whereas the highest vibration was obtained at 9kW load with 49% CO₂ biogas in the lateral direction.

3. CONCLUSIONS

In this paper the main reason for vibration was found in an engine which was run by biodiesel. This paper also focused on the use of H₂ gas and compressed natural gas and how it affects the vibration of the engine. The following conclusions were made based on the investigations carried out by different engineers and researchers:

- Vibration is effected by injector spray and biodiesel have high combustion energy which leads to vibration.
- Waste cooking oil reduces the engine vibration as it has better combustion because of the extra oxygen content and reduced ignition delay.
- Combustion leads to thrust on the piston, which is in the vertical direction which is also a reason for the vibration
- Fuels, which produces more heat release rate will generate a high pressure rise rate, is also a reason for the vibration.
- It was observed that with the increase in the compression ratio the vibration decreases.
- A higher cetane number of the fuel affects the ignition delay and pressure rise improves the combustion characteristics there by lowering the engine vibration
- Biodiesel fuels have more oxygen content and this helps in better combustion quality in the cylinder. As combustion quality improves the vibration of the engine decreases.
- Nano particles of ZnO increase the catalytic behaviour and improve the combustion leading to lower vibration
- Hydrogen mixed with Biodiesel causes an ignition delay, which helps in combustion and reduces vibration
- With the addition of CNG the vibration improved. This can be related to ignition delay.

4. ACKNOWLEDGMENT

This research was supported by The Leading Human Resource Training Program of Regional Neo Industry through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (NRF-2016H1D5A1909917).

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